Coastal Bays Ecosystem Health Index: Bringing it all together

Tim Carruthers[1], William Dennison[1], Catherine Wazniak[2] and Matthew Hall[2]

[1] Integration and Application Network, University of Maryland Center for Environmental Science, Cambridge, MD 21613

[2] Maryland Department of Natural Resources, Tidewater Ecosystem Assessment, Annapolis, MD 21401

Introduction

So, how are the Coastal Bays doing environmentally?

This simplistic, but commonly asked, question drove the research that went into each chapter in this document. The preceding chapters described the environmental status and trends of the many ecosystem indicators monitored in the Maryland Coastal Bays to provide a tracking point for how the bays are faring. While many of these indicators showed improvements throughout the bays, such as seagrass acreage, others had definitive downward trends, such as forage fish abundance. Narrowing the geographic scope, status and trends in several ecosystem elements varied, sometimes widely, between bay segments. Likewise, if tributaries and the open water bays are separated and compared, marked differences in indicator values, especially water quality, become apparent. These broad results begin to answer the question, but may be considered too broad and too convenient for some inquiries.

The purpose of this document was to provide a comprehensive assessment of ecosystem health for use in driving policy decisions. Though the information contained in each chapter and the status of the various indicators contained within are important individually, especially to stakeholders interested in one or a few indicators, those who are responsible for making decisions affecting the ecosystem often request more comprehensive answers. To this end, and as a first attempt at answering the question posed at the beginning of this section, an estuarine health index was developed based on the results of this report. This index also serves as a summary to the document as a whole.

Estuarine health indicators comprised of water quality, living resources, and habitat features were used to compare the different bay segments within the Maryland Coastal Bays. The selected estuarine health indicators are responsive to human activities and were measured throughout the Maryland Coastal Bays. Three water quality indicators (water quality index, brown tides, macroalgae), three living resources indicators (benthic index, hard clam abundance, sediment toxicity), and three habitat indicators (seagrass area, wetland area, natural shoreline) were used to rank the estuarine health in each embayment. Though the index covers a wide variety of indicators used in the preceding report, its coverage is not exhaustive. For instance, no stream or fisheries indicators were used to create the index. Furthermore, all of the indicators used were weighted equally in the analysis.

Analysis

For each of the nine indicators listed above, average values over each of the Coastal Bays segments were calculated. Each indicator was scored based on the data in the preceding report as follows:

<u>Water quality index</u>
The water quality index was a within-segment average of the water quality index values calculated for each Coastal Bays fixed station. This index was calculated from three-year median values for total nitrogen and phosphorus, chlorophyll *a* concentration, and dissolved oxygen concentration. Please see Chapter 4.4 for a detailed explanation of how the water quality index was calculated as well as values for each station.

<u>Brown tide</u>
Maximum brown tide range within each segment for the three-year period between 2001 and 2003 was used (see Chapter 7.1, especially Figure 7.1.1).

<u>Macroalgae</u>
Maximum total macroalgal biomass per square meter (g/m^2) within each segment over the period 1999 through 2003 was used. While raw macroalgal biomass was not reported in this document, the values used for this indicator were the same as those used to develop Figure 6.3.1 (see Chapter 6.3).

<u>Benthic index</u>
The within-segment mean MAIA benthic index score (2000-2001) was used (see Chapter 8.5).

<u>Hard clams</u>
The average of the number of clams per station within each segment for 2003 was used (see Chapter 8.4, especially Figure 8.4.2).

<u>Sediment toxicity</u>
The mean Apparent Effect Threshold (AET) value, averaged within segment, was used. The mean AET values were not reported, but they were used to develop Figure 5.2.2 (see Chapter 5.2).

<u>Seagrass area</u>
The total seagrass acreage within each segment was used, based on the 2002 survey data (see Chapter 6.1). These values were then converted to a percentage of bottom area for each segment.

Wetland area
Raw within-segment National Wetland Inventory (NWI) acreages from the 1988 through 1989 survey were used (see Chapter 6.4). These values were then converted to a percentage of the total watershed land acreage. Since Isle of Wight Bay and the St. Martin River were considered one segment for this analysis, the scaled value for the combination was used for each in the final analysis (see below).

Natural shoreline
Raw total natural shoreline miles for each segment from the 1989 survey were used (see Chapter 6.5). These values were then converted to a percentage of total shoreline miles taken from the same survey.

Results

Within-segment means served as raw index values for each segment (Table S.1). Raw values were converted to scaled values by setting the lowest score among the segments to zero and the highest to one. Those scores falling between zero and one were scaled accordingly (Table S.2). The set of scaled values was then averaged within segment, resulting in a final estuarine health index value for each segment (Table S.2).

Table S.1: Raw values for each indicator by segment. Indicators are divided into water quality (blue), living resources (yellow), and habitat (green) categories.

Indicator / Segment	WQI[1]	Brown tide[2]	Macroalgae[3]	Benthic index[4]	Hard clams[5]	Sediment toxicity[6]	Seagrass area[7]	Wetland area[8]	Natural shoreline[9]
Assawoman Bay	0.33	35-200	102.35	3.35	0.16	12.04	8	45	72
Isle of Wight Bay	0.53	35-200	250.95	3.07	0.28	10.65	5	16	35
St. Martin River	0.33	35-200	392.7	2.18	0.04	19.01	1	16	52
Sinepuxent Bay	0.85	35-200	46.86	3.5	0.32	10.42	36	61	81
Newport Bay	0.35	>200	10.39	3.4	0.14	13.01	4	23	96
Chincoteague Bay	0.74	>200	315.95	3.6	0.27	8.09	32	45	98

[1]Water quality index ranges from 0 (no reference criteria met) to 1 (all reference criteria met). [2]Cell count per liter. [3]Grams/m^2. [4]Ranges from 1(poor) to 5(good). [5]Clams/m^2. [6]Threshold values based on a range of toxicants from various studies. [7]Percent of segment covered. [8]Percent of watershed. [9]Percent of total shoreline.

Table S.2: Scaled values for each indicator by segment, based on raw values in Table S.1. Final index values are also shown. The same color-coding applies to this table.

Indicator / Segment	WQI[1]	Brown tide	Macroalgae	Benthic index	Hard clams	Sediment toxicity	Seagrass area	Wetland area	Natural shoreline	**Estuarine Health Index**
Assawoman Bay	0.0	1.0	0.8	0.8	0.4	0.6	0.2	0.6	0.6	**0.6**
Isle of Wight Bay	0.4	1.0	0.4	0.6	0.9	0.8	0.1	0.0	0.0	**0.4**
St. Martin River	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	**0.1**
Sinepuxent Bay	1.0	1.0	0.9	0.9	1.0	0.8	1.0	1.0	0.7	**0.9**
Newport Bay	0.0	0.0	1.0	0.9	0.4	0.5	0.1	0.2	1.0	**0.4**
Chincoteague Bay	0.8	0.0	0.2	1.0	0.8	1.0	0.9	0.6	1.0	**0.7**

[1]Water quality index.

Discussion

Final rankings, based on average scaled values, were, from best to worst: Sinepuxent Bay, Chincoteague Bay, Assawoman Bay, Isle of Wight Bay, Newport Bay and St. Martin River (Table S.3). These segment rankings are all relevant to each other; that is, no reference estuaries were used to base ranking. Generally, the pattern of rankings reflects those predicted by most of the indicators used in the preceding document, with northern bay segments demonstrating lower indeces than southern bay segments. These indeces, based on raw values, are summarized in Table S.3, which should be referenced throughout the rest of this discussion.

Sinepuxent Bay had the highest ranking of 0.9 because it scored the highest or near the highest for all indicators. This highest ranking reflects this segment's small, relatively undeveloped watershed. Sinepuxent Bay is also well-flushed, due to its proximity to the Ocean City Inlet.

Chincoteague Bay ranked second, at 0.7, largely due to relatively high levels of brown tide and macroalgae. High seagrass area and natural shoreline mileage and low sediment toxicity values contributed to the relative health of this largest segment of the Coastal Bays. Like Sinepuxent Bay, Chincoteague Bay is relatively undeveloped, due to its proximity to the protected Assateague Island National Seashore, but has a much larger watershed.

The third-ranked segment was Assawoman Bay with an index value of 0.6. A low water quality index (identical to last-ranked St. Martin River), due to high nutrient and chlorophyll *a* levels, as well as very low seagrass area drove this ranking. Grey's and Roy's Creeks, and the ditch connecting Assawoman Bay to Little Assawoman Bay in Delaware contributed the most to the low water quality index value. Assawoman Bay was saved from a lower ranking due mainly to very low sediment toxicity and brown tide values, and mid-range habitat indicators (except seagrass coverage).

Ranking fourth, at 0.4, Isle of Wight Bay demonstrated reasonable water quality, but low values in all three habitat indicators. Despite being downstream of heavily eutrophic St. Martin River and containing several nutrient-impacted waterways (Turville, Herring, and Manklin creeks), water quality was mid-range for this segment. This could be due to flushing from the Ocean City Inlet. Next to the St. Martin River, Isle of Wight Bay has the most developed watershed in the Coastal Bays. This heavy development has been implicated in the low values of habitat indicators (shoreline, wetlands, and seagrass area).

Newport Bay ranked fifth among the Coastal Bays segments due to very poor water quality. Newport Bay suffers from chronically high phytoplankton concentrations (as evidenced by chlorophyll *a* values) and brown tide blooms, reduced hard clam densities, high sediment toxicity and very little seagrass coverage. Newport Bay is somewhat sheltered, and thus not well flushed. Another contributor to these poor indicator values may be increasing development in the upper reaches of the watershed.

Ranking last, the St. Martin River had the lowest index values for nearly all indicators. This river had the highest phytoplankton and phosphorus concentrations, as well as the lowest dissolved oxygen concentrations (see breakout in Table S.3). All three living resources indicators ranked the lowest in this river, and seagrass and wetlands were nearly non-existant. A combination of poor flushing and heavy nutrient loading from both agriculture and development probably contribute to the decline of the St. Martin River.

Overall, this break-down of the Coastal Bays into segments and the development of this index provides a thumbnail sketch of how the Coastal Bays fare ecologically. The northern bays are doing worse, in general, than the southern bays. Such an index provides a concise report that is easily accessible by stakeholders and interested citizens alike. Those responsible for managing the resources in a certain segment or the bays as a whole will hopefully find this useful, as will citizens living in the individual watersheds. This index also provides a means to summarize a comprehensive report that is based on reams of data and associated analyses.

However, this approach has its drawbacks. First, not all of the data contained in the full report lent itself to use in the index. As a result, some potentially informative indicators were left out altogether. This has partially to do with the fact that the index was developed *a posteriori*, but since the entire report is a compilation of many different studies this was most likely unavoidable. Another issue is the uneven weight given to some indicators. For instance, because only categories and not true values were used, there were only two possible scaled values for brown tide (Table S.2). Thus, at least with those segments receiving a scaled value of 1.0, an underestimation of the impact of brown tide may be present. Of course, simply using mean raw values for brown tide concentration as with the other indicators could alleviate this. Another possible solution is the development of a ranking system based on something other than relative values (i.e., comparison to reference estuaries).

Table S.3: Estuarine health index results, based on raw values. Note that the four components of the water quality index are separated in this representation.

GOOD ESTUARINE HEALTH → POOR ESTUARINE HEALTH

	Sinepuxent Bay	Chincoteague Bay	Assawoman Bay	Isle of Wight Bay	Newport Bay	St. Martin River
Water quality						
Water quality index[1]	0.85	0.74	0.33	0.53	0.35	0.33
Chlorophyll *a* ($\mu g\ L^{-1}$)[2]	5	5	15	11	15	16
Total nitrogen ($mg\ L^{-1}$)[2]	0.35	0.54	1.19	0.84	2.08	1.93
Total phosphorus ($mg\ L^{-1}$)[2]	0.04	0.04	0.05	0.05	0.07	0.09
Dissolved oxygen ($mg\ L^{-1}$)[2]	6.1	6.1	6.1	5.6	6.0	5.5
Brown tide (max. cells μL^{-1})[3]	35-200	>200	35-200	35-200	>200	35-200
Macroalgal biomass (max. $g\ m^{-2}$)[4]	50	320	100	250	10	390
Living resources						
Benthic index[5]	3.5	3.6	3.4	3.1	3.4	2.2
Hard clam density (clams m^{-2})[6]	0.32	0.27	0.16	0.28	0.14	0.04
Sediment toxicity[7]	10	8	12	11	13	19
Habitat						
Seagrass area (% of bay)[8]	36	32	8	5	4	<1
Wetland area (% of watershed)[9]	61	45	45	16	23	16
Natural shoreline (% of total)[10]	81	98	72	35	96	52

1. Ranges from 0 (no reference criteria met) to 1 (all criteria met). Calculated from chlorophyll *a*, total nitrogen & phosphorus and dissolved oxygen (see page 16). **2.** Medians of monthly measurements from 2001 through 2003, from 57 sites (see page 16). **3.** Maximum values, monitored since 1999 at 15 sites (see page 26). **4.** Survey of 388 sites throughout the Coastal Bays in 2001 and 2003 (see page 23). **5.** Combines a range of benthic fauna measurements from 54 sites between 2000 and 2001. Range is from 1 (poor) to 5 (good) (see page 32). **6.** Averages from 1994-2000 from a total of 1499 sites (see page 33). **7.** Apparent Effect Threshold-combines critical levels of a range of toxicants, measured between 1991-1996 from > 900 sites (see page 36). **8.** 2002 aerial photographic survey (see page 21). **9.** Survey carried out in 1988 and 1989 (see page 28). **10.** Aerial photographic survey carried out in 1989 (see page 27).